

LICHEN

Lichens are the first organisms that are able to colonize the rocks after they have cooled. Lichens are made up of two organisms that have a **symbiotic** relationship with each other: an algae and a fungus. There are 26 different algae (17 green, 8 blue-green, and 1 yellow-green) that can combine with either Ascomyocetes (tube fungi) or Basidiomycetes (stem fungi) to produce every color of the rainbow. Lichens are very hardy and can survive up to 5 years in a dehydrated state. They start the soil-forming process by secreting an acid which breaks down the rock. Because all of these rocks are so young geologically, there has been very little time for either chemical or mechanical weathering to have produced soil. In addition, because of the desert environment, the action of the lichens is also a very slow process and has yielded a negligible amount of soil in contrast to that brought in by the wind.



Many-colored lichen.



Lichen-encrusted boulder.

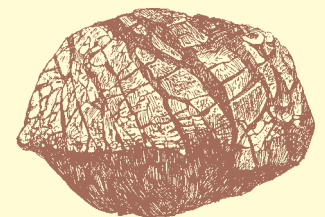


44 feet further and stop at the large breadcrust bomb on the right.

stop **6**

BOMB

This intact breadcrust bomb, which weighs well over one hundred pounds, should give students an idea of the force needed to throw something this large and heavy through the air. Some of the cow pie bombs the students will see later are more than 12 feet across. If you look around, you will see a number of bombs in this area. Some show a hybrid of both breadcrust and spindle characteristics.



Breadcrust bomb.



38 feet further and examine the surface texture of the Broken Top Flow on the left side of the trail.

BROKEN TOP FLOW

When you study the surface of the Broken Top Flow, you will find that the surface is covered with spherical or round pits generally less than a 1/4 inch across. They were caused by gas bubbles and the shape tells us that the lava had to be very hot and fluid in order for the surface tension to keep them round as the lava flowed. Each one of these pits had a bubble above it. From Hawaii we know that the surface of these bubbles is a thin film of glass. Within the first hour of cooling, contraction causes the bubbles to break, flinging glass shards outward. As these glass shards break down (a process called devitrification), they can form clay minerals (soil). Thus, a possible geologic explanation for why the youngest flow in the park has some of the densest vegetation is that the flow made its own soil. If you look to the East, you can see that the flow in this area was sufficiently gas-charged to produce small open tubes, blisters, and thin crusts (about 10 cm thick) and is known as shelly pahoehoe.



► Ask the students to visualize miniature light bulbs.



43 feet further and look at the lava toes on the right side of the trail.

LAVA TOES

The lava toes look like distal appendages of some huge monster that Medusa has turned to stone. These lava toes are the “toe” of this breakout flow from the main body of the Broken Top Flow (further discussion of the Broken Top Flow will be provided at Stop 14, Buffalo Caves). These toes have a beautiful blue-glassy crust. Where this crust has been broken a reddish oxidized material is exposed.



► This glassy layer is fragile and most of the damage exposing the red coloration has been caused by people either walking or climbing on these toes. Please keep everyone off of them.

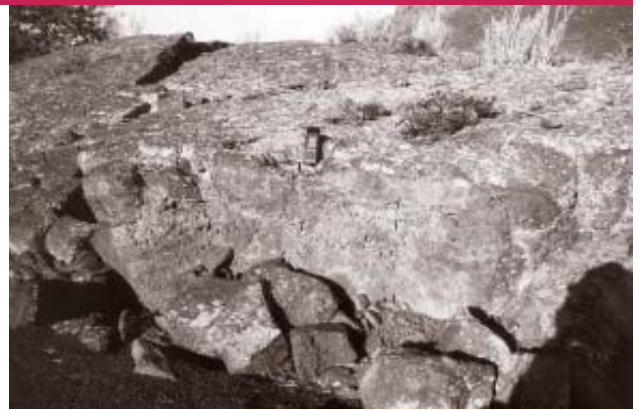
► Compare the picture of relatively undamaged lava toes at left with the toes you are looking at here.



52 feet further and move up onto the pressure ridge.

PRESSURE RIDGE

Pressure or flow ridges like this one are common throughout the park. Once a crust has formed on the surface of a lava flow and more material is added to the base of the crust (because it is the main cooling surface) the cross-sectional area that the stream or river of lava has to flow through is diminished. If the same volume of flow is going to be maintained, the pressure and speed of flow must increase. The increase in pressure often causes the crust to rupture, because the solidified crustal material can no longer stretch. Stretching is a tensional or pulling apart force and the prominent fracture seen running along the crest or top of most pressure ridges is a tension fracture. These fractures widen and propagate down as more and more material is added to the crust. The fractures also widen with cooling. If pressure becomes sufficient at some time after the tension fracture has formed, molten rock can be forced or squeezed up through the fracture to spill down the sides of the ridge in what is called a squeeze up (there is a great example on the North Crater Flow Trail).



Edge of pressure ridge. Move up onto the ridge on the left-hand side.

See p. 5 of Appendix II for a picture of a squeeze up.

The outstanding “Dragon’s Teeth” or saw-edge fractures, which can be seen so well here (some of the best in the park), are a cooling phenomenon. Many materials, including rock, expand when they are heated and contract when they are cooled, and rock when it contracts usually produces polygonal patterns of fractures or joints. You can see this polygon pattern on the surface near the “Dragon’s Teeth.” In thick flows



Dragon’s teeth.

this phenomenon produces columnar structures (columnar joints), often referred to as “Devil’s post piles.” If they are exposed in a cliff face they are called pali-



Students can count the number of sides that these polygons have. If your students have been to Yellowstone National Park near the Tower Fall area, they may have seen some good examples of this type of feature.

sades or colonnades. Mud cracks that form as mud desiccates or dries out are analogous to these cooling cracks and are also caused by contraction (in this case however, the contraction is caused by the clay minerals dewatering and shrinking in size rather than by cooling).

This is also a good spot to discuss where and why plant life gets its first foothold. The cracks are where the plants get their foothold. Cracks offer a lot of advantages:



Syringa – state flower of Idaho – growing in a tension fracture.

1 because the wind speed is less in them they are sites of deposition of wind-blown soil; even at low wind speeds material being rolled or bounced (saltation) along can fall into them; **2** large cracks provide shelter from the wind, which can rob moisture from plants; **3** cracks can also provide shade, making it cooler – the sun can heat these black rocks to more than 150°F during the summer; and **4** cracks are natural traps for moisture, e.g., in winter cracks fill with snow, which slowly melts in the spring, and cracks are low spots for water to flow into, when the rain is heavier than the ability of these porous rocks to absorb it.

► Have the students look around. Ask them to identify where most of the plants seem to be growing.

► This a good area to study 3 of our prominent shrubs: syringa, fern bush, and rockspirea. Look for them in the big cracks. Descriptions are found in Appendix II.



► **PROCEED ...**

370 feet toward Buffalo Caves, stopping to look into some of the small lava tubes and stop where the ferns are growing.

FERN

Ferns are not a plant one expects to see in the desert, because their leaves have too much surface area from which to lose moisture. Here at Craters of the Moon, ferns tend to be found in either very deep cracks that provide shade almost the entire day, shelter from the wind, and moisture from the melting snows that filled them during the winter, or in cracks that have a connection to lava tubes. Many lava tubes accumulate ice during the winter, which melts very slowly over the summer. Some of the lava tubes here at Craters of the Moon (e.g. Boy Scout Cave) hold ice all summer long and you can still see ice in them in the fall. When the wind blows across cracks, it can pull cool moist air from the lava tubes creating a micro or small environment which can sustain the ferns. The ferns growing at this stop are Christmas ferns.



Christmas fern gets its name because it is evergreen and is used as a Christmas decoration.

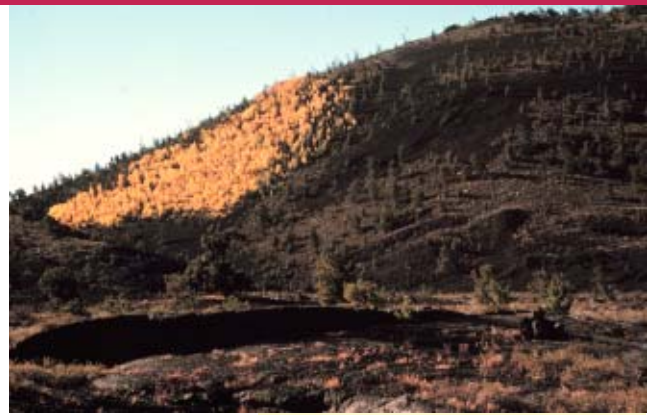


► **PROCEED ...**

204 feet to Buffalo Caves.

BUFFALO CAVES

Lava tubes are the main way in which pahoehoe lavas get distributed. Once a stream or river of lava crusts over, the crust acts like an insulator reducing the heat loss to the air, and allows the molten rock to be carried further from the vent before it solidifies. Much like ice on a river with water flowing beneath the ice. The crust also makes the river of lava into a tube in which the crust serves as the pipe within which the molten rock is flowing. As the volume of lava being released from the vent vacillates, the tube may sometimes be filled to the top and at other times be only partially filled. When the vent stops feeding the tube, and if the tube has an opportunity to drain, then the tube is left behind as a cave.



Buffalo Caves with Big Cinder Butte in the background.

Buffalo Caves is a series of lava tubes that got their name from a bison bone that was found in one of them. The ultimate fate of all lava tubes is to collapse. The students are standing on top of a hot collapse where the ceiling of the tube collapsed and fell the distance from where you are sitting to where your feet are. The ceiling was hot enough to drape down in a plastic fashion, as opposed to the collapse (rubble pile) just to the north of this one that collapsed after the ceiling was cool enough (solid enough) to break in a brittle fashion. Water freezing and expanding in cracks, the action of plant roots, or a major earthquake are the most likely agents that will lead to the eventual collapse of the lava tubes here at Craters of the Moon. A section of Buffalo Cave is closed because of freeze-thaw action has weakened the ceiling and collapse has begun.

Do not go beyond warning signs within the cave.

▶ **Cross to the far side of the collapse and sit down on the ledge formed by the collapse and leave the students standing on the collapse. Ask the students if they know what they are standing on.**

▶ **A number of bones can still be found in Buffalo Caves. Please leave them where they are so that others can also enjoy the thrill of discovery in the future.**

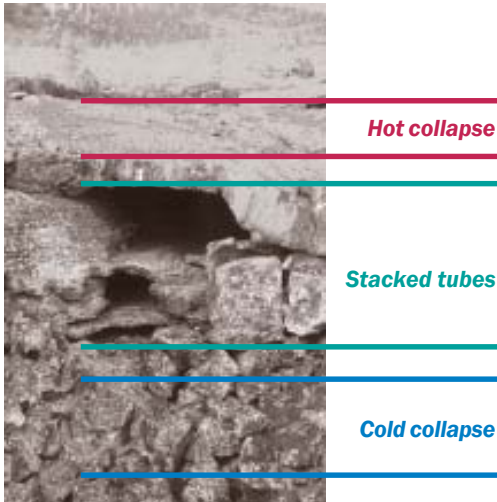
▶ **PROCEED ...**

clockwise around the edge of the collapses until you can see the lava curbs and stacked tubes.

The series of rock shelves along the far wall of the tube, which here are about a foot wide, are called lava curbs or bathtub rings. The curbs represent a level at which the lava flowed for a long enough period of time for ropes or ripples of congealing lava moving along the surface of the flow to accumulate at the edges of the stream of molten rock producing the curbs.

SAFETY MESSAGE

If you go down to where the curbs are, please ask students not to climb on them!



Stacked tubes.



Lava curbs.

If lava flows at a lowered level within a tube for a long enough period of time, a new internal ceiling can form. If the flow from the vent feeding the tube drops in increments, a whole series of new ceilings can be formed internal to the original tube producing a series of stacked tubes. A tube that flows for a long time can also soften the floor it is flowing over and gradually erode its way down, which also can generate new curbs and ceilings.

If you would rather go through a lava tube that is much larger and easier to travel through, we recommend visiting either Indian Tunnel or Beauty Cave, which are located in the Caves Area, a five-minute drive from where you are now parked.



Vault near lava curbs.



The lava stalactites or “lava icicles” hanging from the ceiling form as molten rock clinging to the ceiling flows and drips towards the floor under the tug of gravity, while the tube is draining or splashed there to do the same thing. Once formed, these stalactities do not continue to grow as do the stalactities in limestone caves. Lava stalagmites are very rare because the floor of the tube is a stream of moving lava, and when it stops moving the ceiling is usually too cool for lava to drip down and form stalagmites.

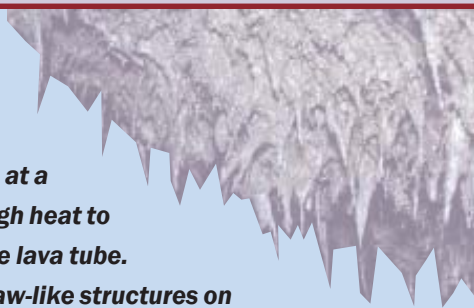
Some coatings and crystals are still forming or growing today. Water percolating through cracks and pores in the lava dissolves very tiny amounts of the rock over time and precipitates it as it evaporates on the inside of the lava tube. The white coatings that you see in places on the ceiling and walls of the lava tube are such material. The composition of the material has been identified as sulfate compounds. In some places you can see delicate flower-like crystals of sulfate. The sulfate is made up of a metallic ion, like iron, plus the SO_4 radical.

There are also some tan stains near some of the large cracks in the roof. The tan is some of the loess we discussed earlier. It has been physically brought in as water infiltrated along the cracks and carried the loess with it.



REMELT STRUCTURES

There are times when the inside of a lava tube can remelt. A stream of lava sometimes flows long enough at a lower level and radiates enough heat to remelt the top and sides of the lava tube. Remelting produces soda-straw-like structures on the tips of the lava stalactites. Remelted basalt when it recrystallizes takes on a submetallic or silvery appearance because of lack of dissolved gases. Good examples of remelt can be seen in Beauty Cave at the Caves Area.



FOR SAFETY, SERIOUS CAVING, SUCH AS IN CRAWLS REQUIRES:

- 1 Minimum party of three
- 2 Three independent sources of light
- 3 Hard hats
- 4 Knee pads
- 5 Work gloves

Please ask students not to touch any of the crystals. The crystals are fragile and the oils from human skin can stop them from growing.

The most common mineral is believed to be sodium sulfate. Small amounts of calcium carbonate may also be leached from some of the loess and deposited in the tubes.

SAFETY MESSAGE

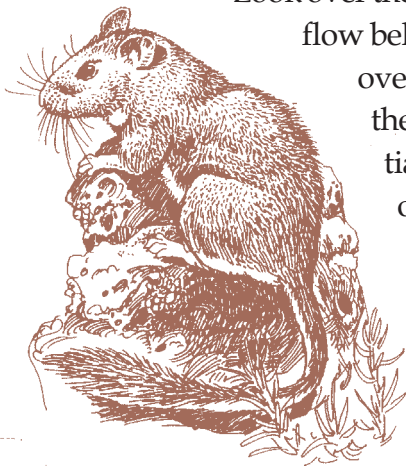
NO CAVE IS A 100% SAFE! You know your students and their abilities. Factors to consider include the size of your group, the ability to provide close supervision in a cave, and having the proper equipment. If you do not think that every student will have a safe trip through the lava tube, you should not enter the cave.

Throughout Buffalo Caves there are a lot of pack rat droppings, which look similar to cocoa crispies. Pack rats are common in many of the lava tubes, because the tubes afford them some of their favorite habitat, i.e., caves.

After you leave Buffalo Caves proceed out onto the flow so that students can get a nice feel for the Broken Top Flow (BTF). BTF was a sheet flow; look toward Big Cinder (south) and imagine a lake of lava sitting here. Picture the lava coming to the surface a few hundred feet in front of you, then fanning out, including flowing back to where you are now standing. Sheet flows usually start out somewhere between knee and waist deep in these continental basalts and, as more and more lava feeds into them, they get thicker and thicker.

Look over the edge of the

flow behind you; the total thickness of the BTF is over twice the thickness that you see here on the east side of Half Cone. As the BTF initially came up against the edge of the cone of Broken Top, it couldn't go any further and the surface solidified. As more and more lava inflated the sheet flow, the already solidified crust at the edge was tilted up.



Pack rats like to gather stray objects – particularly shiny things.



You are here.



Edge of Broken Top Flow east of Half Cone.



► PROCEED ...

310 feet back and pick up any gear you left outside the entrance to Buffalo Caves and pick up the trail, which is marked by rock cairns. Walk until you get to the limber pine with the incredible exposed root.

ROOT

The root of this limber pine is a testimony to the will to survive and the tremendous quest for water that these trees have. You can have a student “heel-toe-it” to measure the length of the root that is visible, and should come up with about 40 feet.

Just a little beyond the root on the side of the cone is an open fissure. This fissure has opened since Broken Top Cone was deposited. Perhaps it will be the weak spot magma will follow to the surface in the future.

This side of Broken Top Cone is covered with volcanic bombs that flattened on impact. Because they went splat on impact they are called cow-pie bombs. They were at the least still plastic when they landed and many probably contained a fluid core. Some are as much as 12 feet across. The surface of some of them show both ripples and also breadcrust textures.



Open fissure. View from trail.



Aerial photograph showing open fissure and other rifting not as evident standing on the ground. The area of densely spaced fractures above eruptive fissure is where the cone has been slumping or sloughing back into the fissure.

Slump zone

Rifts

As you proceed on down the trail you will be passing a finger of lava. It is estimated that it took between 10 and 20 minutes for this small stream of lava to flow to where it stopped. In general the smaller the stream of lava the slower it flows. Even very large tubes like Indian Tunnel were probably flowing at less than 10 miles per hour. This finger of lava is very special; it is covered with a natural bonsai-like garden. Stunted by the harsh growing conditions, dwarf goldenweed, limber pines, and others look like miniatures of giant trees.



Lava finger.

► *Please do not let students climb, walk, stand, or sit on the finger of lava, so that this bonsai garden will be here for future generations to enjoy.*



► **PROCEED ...**

315 feet to where the steeply dipping edge of the sheet flow has been lifted up and lava fingers have poured out from beneath. *Remind students to stay on the trail.*

BREAKOUT

Breakouts from the sheet flow or lava lake occurred at the end of the Broken Top Flow eruption. Because of its plateau-like appearance, another name for the feature before you is a pressure plateau. It is produced by the sill-like injection of new lava beneath the crust of an earlier flow that has not completely solidified. Lava found a weak spot here and was forced up the steeply dipping plate at the edge of the flow and escaped. Because of its proximity to the flank of the cinder cone, the lava from this breakout had only two possible ways to flow. Facing the breakout from the trail, the lava flowed downhill to both the right and the left, producing the blue, glass-covered lava fingers and toes.



*West side of pressure plateau as seen from the air.
Note steep edge of pressure plateau.*



*Keep an eye out for
yellow-bellied marmots.*

► **PROCEED ...**

375 feet to the fenced viewing area
for the inflation structure.

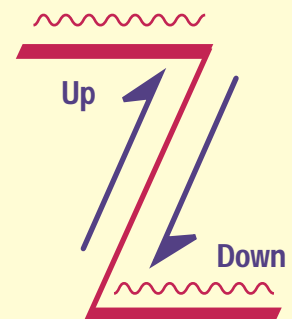
INFLATION

Inflation structure is common throughout the pahoehoe flows in the park. The one seen here is a textbook example that is easy for students to see. Lava may have hit a topographic high or an obstacle and couldn't flow any further because it didn't have enough energy to flow over or around it. (Remember, the primary force that causes lava to flow is gravity.) But that doesn't mean that all the forces acting on the lava have been neutralized. The vent may still have poured out more lava, and gasses dissolved in the lava may have continued to come out of solution. Either or both of these events can exert tremendous pressure on an already solidified crust. These pressures can cause the crust to rupture and very slowly rise, not unlike the crust of a casserole in the oven when water in the casserole changes to steam.



Inflation structure with reverse fault type movement. Note how ropes have been offset on the left.

Geologists in Hawaii, watching these structures form, report a glowing line at the fracture and a growth rate or movement rate which can be as little as a fraction of an inch an hour. What you see before you may have taken days to form! Because this is an expansive or growth process the normal observed sense of motion along the fracture is that of a reverse fault with the up-thrown side slightly overhanging the other. As the structure grows and the one side grinds past the lip of the original crust, vertical scratches or striations are often left on the up-thrown segment, as can be seen here. The pahoehoe ropes that were on the surface of the original crust are nicely offset on the left side of this inflation structure.



► **PROCEED ...**

130 feet to the viewing area
for the pahoehoe ropes.

ROPE

For a good analogy for these beautiful pahoehoe ropes, compare them to a thick cake or brownie mix. When the batter is poured into a baking pan from the mixing bowl, it also forms ropes. The ropes form because, while the batter in the center of the pan flows rather quickly, the batter at the edges of the pan is slowed by the friction developed as it drags on the pan's sides.

Ropes are useful to a geologist because they provide a direction of flow at the time the crust solidified. The convex arch points in the direction of flow. Younger students are not going to be familiar with what convex means, so the following analogy should be useful: pretend each rope is an archer's bow and if you attach an imaginary string and drop in an arrow, the direction the arrow would fly is the direction the lava was flowing.



Ropy pahoehoe.

▶ *Perhaps the students could make brownies in school the day before the trip and bring them as a snack.*

▶ *Keep in mind that after a section of ropy pahoehoe forms it can be broken and spun around like ice bobbing in a river.*



60 feet to the next viewing area along the lodgepole pine barrier.

CONTACT

The lava toes with the pale to dark-blue glass (breakouts from the Broken Top Sheet-Flow or lava lake) clearly have flowed out on top of the Blue Dragon Flow. Besides the nice sharp contact between the two flows there is also a marked difference in their surface textures, which is a reflection of their viscosities. The Blue Dragon Flow was very thick and pasty, probably close to becoming aa. The flow was so thick and pasty that gas bubbles that came to the surface coalesced and were stretched into elongate ovals up to 4 or more inches in length. This kind of pahoehoe

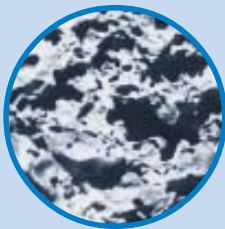
► *This is a great place to review or reinforce the law of superposition, which you may have discussed with either older students or with earth science students.*



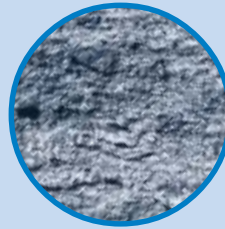
LAVA TEXTURES

*As you have made your way around the loop, you have seen 3 distinctly different surface textures representing 3 different viscosities of pahoehoe lava: **1** spherical gas bubbles on the Broken Top Flow — hot and very fluid or low-viscosity pahoehoe; **2** slightly stretched gas bubbles on the Broken Top Sheet-Flow breakouts — relatively fluid or intermediate-viscosity pahoehoe; and **3** highly stretched and elongated bubbles on the Blue Dragon Flow — very thick and pasty or high-viscosity pahoehoe on the verge of becoming aa that can shear, producing slabby pahoehoe.*

1



2



3



hoe is known as spiny pahoehoe. Just a little shearing will cause it to change into slabby pahoehoe (discussed in the section between the parking lot and eruptive fissure stops). In contrast the gas bubbles on the surface of the lava toes from the Broken Top Flow breakouts are usually only stretched an inch or less, indicating that it was much more fluid than the Blue Dragon Flow.



► **PROCEED ...**

205 feet to the fenced off lava billows at the top of the hill across the way, noting the many fine examples of pahoehoe ropes along the way.

BILLOWS

The lava here had just the right taffy-like quality to fold into these remarkable billows. The lava here got stopped as it ran into a barrier and, as material continued to move toward that barrier, bunched up into tight folds. The lava was not so hot and fluid that it flowed back together and not so thick that the forward motion caused it to shear and chew itself up.



► *An analogy to help students envision this happening: Ask them to think of a table cloth on a polished table. If they anchor the table cloth with one hand and with the other hand push the table cloth toward their anchored hand, it will glide and fold into billows. Or, have them think of their dog running across the kitchen floor and suddenly hitting a throw rug and bunching it up.*

► **PROCEED ...**

160 feet to the overlook into the eruptive fissure just above the small switchback in the trail.

WRAP UP

Look back toward the east between Broken Top and Big Cinder Butte and you will see a crescent-shaped volcano. It is called Crescent Butte and it is the oldest (~ 15 Ka) volcano on the surface here at Craters of the Moon. Big Cinder Butte on your right is the largest volcano in the park and Broken Top on your left is one of the youngest volcanoes (~ 2.1-2.2 Ka).



The sequence of events in this immediate area was as follows:

1 the eruptive fissure you are standing next to opens along the Great Rift and Broken Top Cone is built from material ejected from it; **2** the Blue Dragon Flow comes from the northwest, sweeps around, and partially fills in the eruptive fissure; **3** the Broken Top Sheet-Flow is poured out onto the surface (this is the smooth, level area visible to the east); and **4** breakouts from the Broken Top Sheet-Flow / Lava Lake / Pressure Plateau occur. The breakouts as seen from here form

the contorted (jumble of lava toes and fingers) level between the Blue Dragon Flow and the Broken Top Flow.



Eruptive fissure.

► In 310 feet, the trail to the parking lot will intersect with the loop. Turn left and walk another 690 feet to the lot.



We hope you had a safe and rewarding educational experience.